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Building the IDEAL* home

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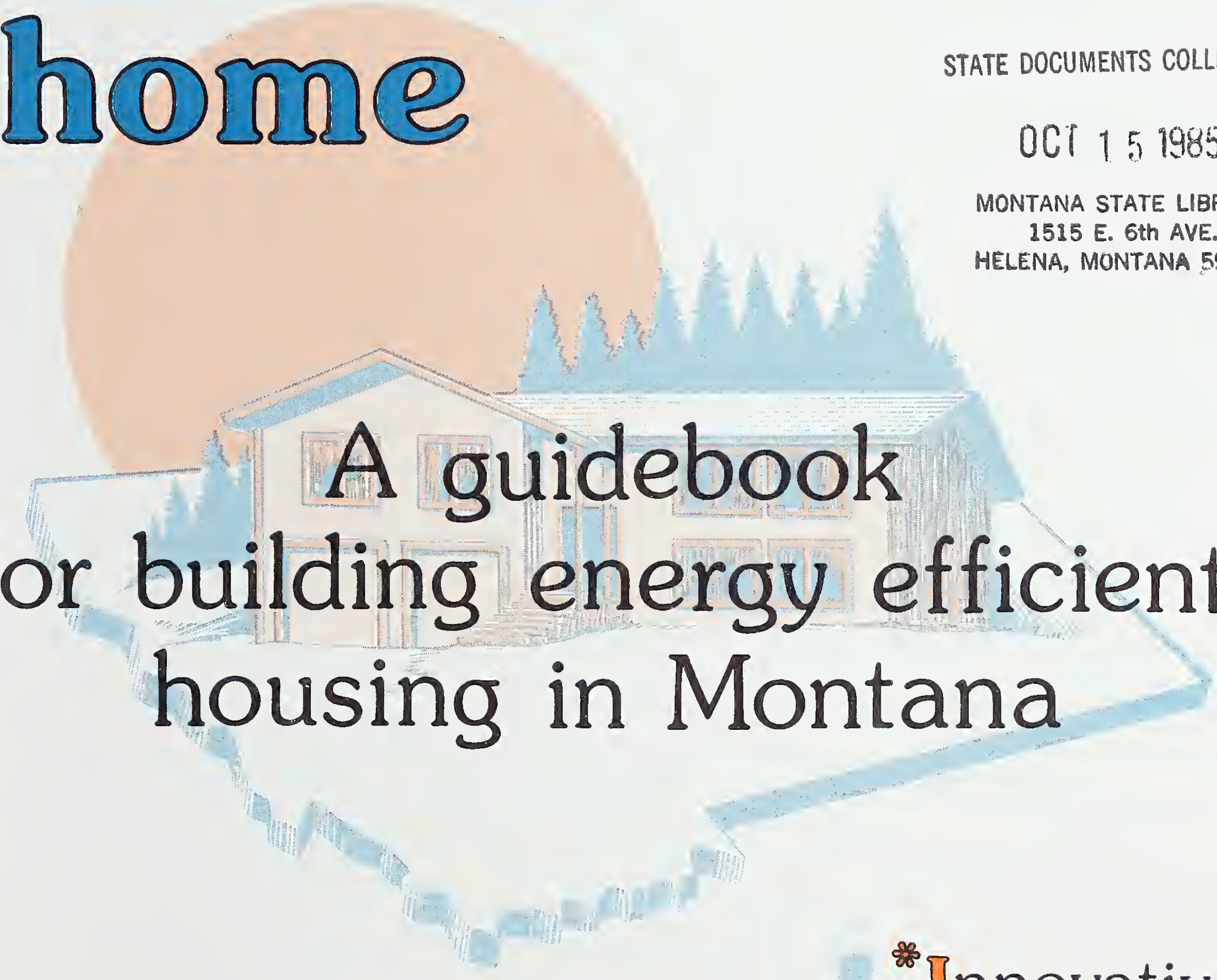

A guidebook for building energy efficient housing in Montana

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Montana Department of
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*Innovative
Designs for
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Building the IDEAL home :a guidebook for
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INTRODUCTION

In the late 1970s and early 1980s, builders throughout the United States and Canada first heard about a new building concept called "superinsulation". In the last two years, Montana homebuilders have read countless reports and magazine articles on energy efficient home construction, including superinsulation.

The Montana Department of Natural Resources and Conservation (DNRC) has received many requests for information on energy efficient homebuilding. To help fill this demand, DNRC is reprinting this booklet on the IDEAL home. Originally produced by the Iowa Energy Policy Council, this booklet outlines the basic technology common to all energy efficient structures. The following information briefly describes those features that should be considered by anyone building a new home.

As with any technical information, a little knowledge can be a dangerous thing. This is especially true of energy efficient homebuilding. Building an energy efficient home involves more than simply stuffing an extra batt of insulation into the walls. As this booklet explains, an IDEAL home encompasses increased levels of insulation, tighter windows and doors, passive solar orientation and the combination of a continuous air/vapor barrier, passive solar orientation and a controlled ventilation system.

Incorporating an air/vapor barrier without installing an adequate controlled ventilation system can lead to excessive indoor humidity or to potentially harmful levels of indoor air pollution. An even more serious problem could develop if combustion appliances such as gas furnaces or water heaters are installed in an airtight house. Without adequate ventilation, these appliances could release potentially toxic levels of gases such as carbon monoxide into a tightly constructed energy efficient home.

DNRC is currently conducting two programs to evaluate the costs and energy saving potential associated with energy-saving construction practices. In 1984, under a program funded by the Bonneville Power Administration, DNRC provided incentives for the construction of 68 energy-saving homes in western Montana. The program did not require superinsulation, but featured moderate levels of insulation, tighter doors and windows, continuous air/vapor barriers, and air-to-air heat exchangers (one type of controlled ventilation).

Simultaneously, DNRC contracted with the National Center for Appropriate Technology in Butte to build five identical superinsulated homes in eastern Montana. All of these homes were completed by early 1985. During construction, costs data was collected to determine what energy-saving measures were cost effective. These homes are now being extensively monitored to determine their space, appliance and water heating costs. In addition, heat exchanger performance and the effect of lifestyle on energy consumption are being analyzed. Indoor air pollution will be monitored in most of these homes as well.

As a result of these programs, we hope to document which energy-saving measures provide the optimum balance between construction costs, energy savings, and occupant comfort. Unfortunately, we do not yet have all of these answers. Actual heating costs, heat exchanger performance, and indoor air pollution data will not be analyzed until late 1985 or early 1986. However, a few conclusions on energy efficient construction in Montana have already been drawn.

The overall effectiveness of air-to-air heat exchangers in Montana's energy efficient houses is not yet known. Initial studies have shown that some heat exchangers may freeze up in cold weather. Other problems have been identified—high energy consumption by some heat exchangers, improperly balanced airflows, improper duct design and cold supply air in the home. An effective heat exchanger requires proper installation and maintenance, manufacturer support, and homeowner education about heat exchanger operation. Without these procedures, frustrating problems have occurred in some of Montana's energy efficient homes. DNRC believes that other types of ventilation should be considered.

Another area of debate is the actual heating costs of energy efficient homes in Montana. This booklet discusses possible heating bills of $100 to $300 a year in Iowa. Initial data for the Montana homes indicate that these estimates may be low for our state. Differences in fuel types, as well as lifestyle, can dramatically increase yearly utility expenses. In addition, keep in mind that the $100 to $300 figure mentioned in this booklet applies only to your yearly space heating bill. Other utility costs, such as water heating and appliance use, can more than double your monthly utility expenses.

The energy efficient IDEAL home described in this booklet is but one method of energy efficient construction. Other building techniques also incorporate energy efficient design. Under certain conditions, more moderate levels of insulation and tight construction practices might be more cost effective. In other instances, high efficiency heating systems, earth berming or passive solar features such as increased thermal mass and southern glazing may be a better investment than the concepts described in this booklet. Consider incorporating the practices outlined here, but consult your builder before designing your new home. In addition, contact the Montana Department of Natural Resources and Conservation for the latest research information on other energy efficient homebuilding techniques.

This booklet was reprinted in April 1985 with funds from the Bonneville Power Administration.

BUILDING THE IDEAL HOME

While the concept of the IDEAL home is new, the building components have been around for decades. Most of the materials are standard construction items and the techniques are familiar. Careful installation and attention to details are critical.

4 Key Elements

There are four key design elements in the energy saving package installed in an IDEAL home.

- high levels of **insulation**, far beyond conventional practice.
- a continuous **vapor barrier** to make the structure "air tight" and protect insulation from condensation.
- an air-to-air **heat exchanger** to keep indoor air fresh without losing heat.
- **passive solar** orientation with moderate amounts of south-facing windows to collect solar energy.

Superinsulated Home

A home that combines all of these features is often called a superinsulated home. The concept of superinsulated homes evolved as solar energy researchers found that a house must have a low heat loss for any solar energy system to make a significant contribution. It became clear that a balanced combination of energy-conserving and passive solar features is critical for efficient energy use. With additional insulation and tighter construction, fewer south-facing windows (less solar energy) are needed to keep the house warm, simplifying the passive solar construction.

Less Expensive Heating & Cooling Systems Required

Another advantage of a superinsulated house is that it requires a smaller, less expensive heating and cooling system than a conventional structure of the same square footage. The resulting savings help to offset the additional cost of superinsulating. A sizeable portion of the heat needed comes from moderate amounts of south-facing glass that collect solar energy. Considerable amounts of heat are also supplied by the water heater, stove, refrigerator, light bulbs and other appliances. In a conventional house, these "internal gain" heat sources are usually insignificant. But with tight and heavily-insulated construction, they make substantial contributions.

$100–$300 Annual Heating Bill

The result is that heating bills for a superinsulated house are extremely low—less than $100 per year in the best insulated models. The annual heating bills for IDEAL homes will range from approximately $100 to under $300. This of course will vary with the weather, size of the house, lifestyle of the occupants and the type of fuel used.

INSULATION

A superinsulation system demands both quantity of insulation and quality of workmanship to be effective. The entire "envelope" of the house—ceiling, walls, windows and foundation—must receive thorough attention to minimize heat loss. The recommended R-values for insulation are shown in Table 1. R-value refers to the material's ability to stop heat from passing through it; the higher the R-value the greater the Resistance to heat loss.

R-40 — R-60 in the Ceiling

Table 1. **Recommended insulation levels for energy efficient houses.**

	R-Value Range
Ceiling	40 — 60
Walls—east, north, west	27 — 40
Walls—south	20 — 30
Foundation walls	10 — 20
Floors over unheated spaces	20 — 30
Window shutters	5 — 10

The recommended R-values can be achieved by either using one type of insulation or several types in combination. When several layers are used, the total R-value is simply the sum of the individual components. This is shown for several wall constructions in Figures 4 to 6. Table 2 shows lists of common insulating and building materials and their R-values.

Table 2. **Insulation R-values for building materials.**

(a)

Material	Resistance Per Inch of Thickness	Resistance For Thickness Shown
Block, concrete		
Filled cores		
4 inches		2.33
8 inches		4.85
10 inches		5.92
Open cores		
4 inches		1.40
8 inches		1.75
10 inches		1.97
Doors, metal, insulated		5-7
Doors, wood, 1½ in.		2
Doors, wood with storm door		3
Glass doors, windows		
Single		0.90
Double		1.70
Triple		3.20
Insulation — batt - see Table 2b		
Insulation, fill		
Perlite	2.70	
Vermiculite	2.27	
Cellulose	3.13	
Insulation, rigid		
Cellular glass	2.63	
Fiberglass	4.00	
Mineral fiber, resin binder	3.45	
Mineral fiberboard, wet felted, roof insulation	2.94	
Wood, shredded, cemented in performed slabs	1.67	
Polystyrene—cut cell surface	4.00	
Polystyrene — smooth skin surface	5.26	
Polystyrene — molded bead	3.57	
Polyurethane	6.25	
Polyisocyanurate foam, plastic core, and foil each face	7.2	
Miscellaneous		
Acoustical tile, ½ in.		1.25
Asbestos—cement, ¼ in.		0.06
Brick-face, 4 in.		0.44
Carpet, fibrous pad		2.08
Carpet, rubber pad		1.23
Floor tile, asphalt, rubber, vinyl		0.05
Gyp board, ½ in.		0.45
Particle board, ⅝ in.		0.82
Plaster, ½ in.		
Cement, sand, agg.		0.10
Gyp, L.W. agg.		0.32
Gyp, sand agg.		0.09
Roofing, ⅜ in., built up		0.33
Wood, hard	0.91	
Wood, soft	1.25	
Wood, plywood	0.83	

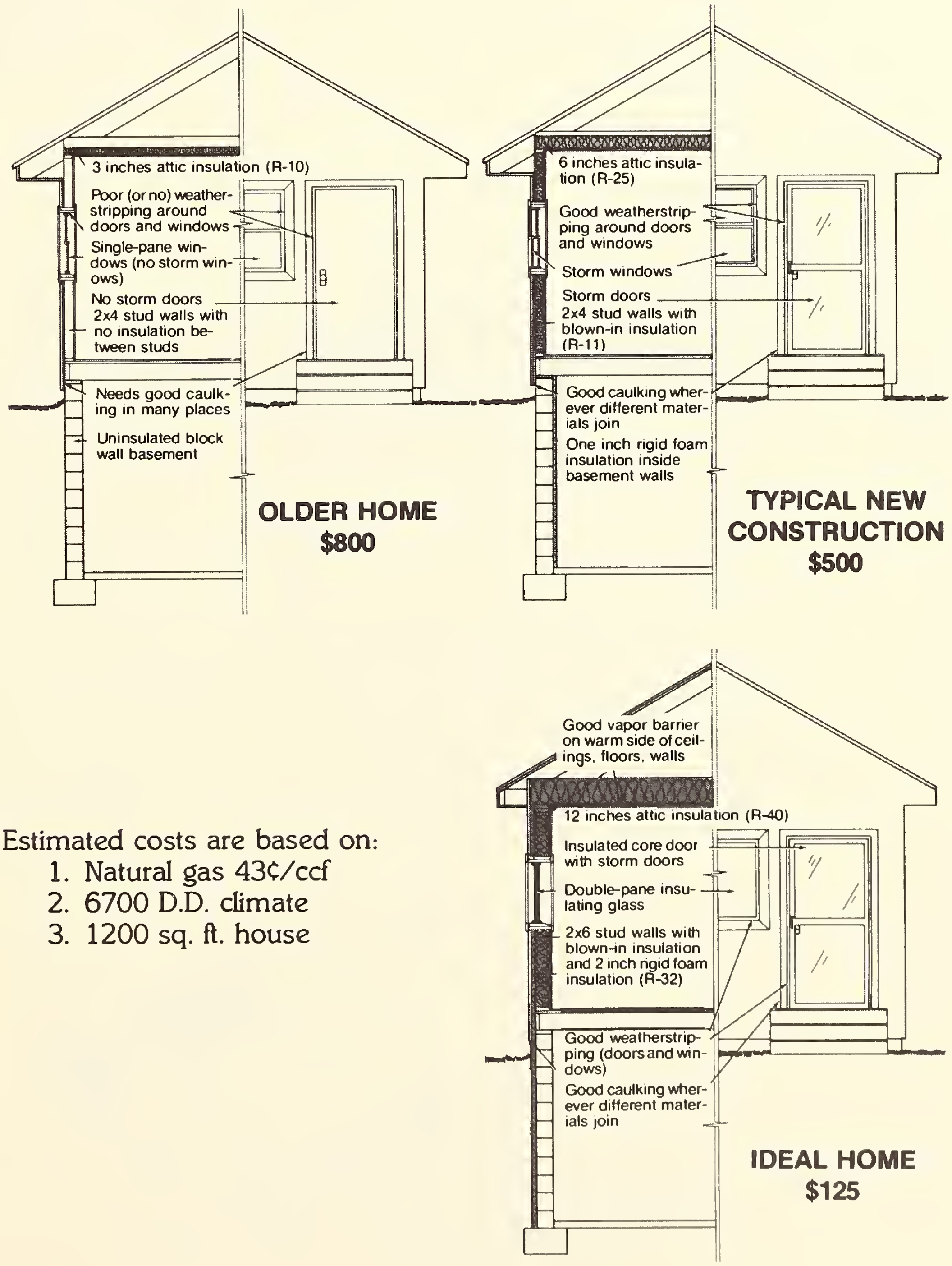
(b)

Fiberglass Insulation Sizes Commonly Available	
	Blowing Wool
R-2.2	per in. of thickness; bags
	Foil-Faced
R-19	6" x 15" or 23" x 32' roll
R-19	6" x 15" or 23" x 45" batt
R-11	3½" x 15" or 23" x 56' roll
	Kraft Paper Faced
R-30	9" x 16" x 48" batt
R-30	9" x 24" x 48" batt
R-26	8¼" x 16" x 48" batt
R-22	6½" x 15" or 23" x 48" batt
R-19	6" x 15" or 23" x 48" batt
R-11	3½" x 15" or 23" x 56' roll
R-11	3½" x 15" or 23" x 48" batt
R-11	3½" x 15" x 93" or 96" batt
R-11	3½" x 11" x 48" batt
	Semi-Rigid Board (for sheathing and foundations)
R-4	per inch
	Unfaced Friction-Fit
R-30	9" x 16" x 48" batt
R-30	9" x 24" x 48" batt
R-26	8¼" x 16" x 48" batt
R-26	8¼" x 24" x 48" batt
R-22	6½" x 15¼" x 48" batt
R-19	6" x 15¼" or 23¼" x 48" batt
R-19	6" x 15¼" or 23¼" x 48" batt
R-13	3⅝" x 15¼" x 47" batt
R-11	3½" x 15¼" x 93" or 96" batt
R-11	3½" x 23¼" x 48" batt

Table 3. Insulation thickness required for roof.

	R-40	**R-60**
Fiberglass or mineral wool	12 inches	18 inches
Cellulose	10 inches	15 inches
Vermiculite	18 inches	27 inches
Extruded polystyrene boards (such as styrofoam)	7 inches	11 inches
Expanded polystyrene boards (beadboard)	10 inches	15 inches
Polyurethane foam or boards	6 inches	9 inches

Figure 1 Comparison of annual heating costs.*


3 inches attic insulation (R-10)
Poor (or no) weather-stripping around doors and windows
Single-pane windows (no storm windows)
No storm doors
2x4 stud walls with no insulation between studs
Needs good caulking in many places
Uninsulated block wall basement
OLDER HOME
$800
6 inches attic insulation (R-25)
Good weatherstripping around doors and windows
Storm windows
Storm doors
2x4 stud walls with blown-in insulation (R-11)
Good caulking wherever different materials join
One inch rigid foam insulation inside basement walls
TYPICAL NEW CONSTRUCTION
$500
Good vapor barrier on warm side of ceilings, floors, walls
12 inches attic insulation (R-40)
Insulated core door with storm doors
Double-pane insulating glass
2x6 stud walls with blown-in insulation and 2 inch rigid foam insulation (R-32)
Good weatherstripping (doors and windows)
Good caulking wherever different materials join
IDEAL HOME
$125

*Estimated costs are based on:

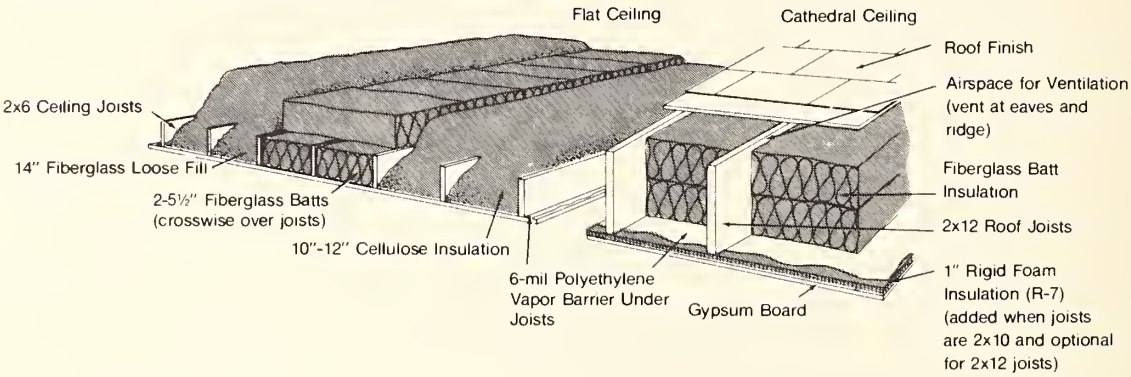
1. Natural gas 43¢/ccf
2. 6700 D.D. climate
3. 1200 sq. ft. house

Ceiling Insulation

Attic Ventilation Important

An attic normally provides ample room to install adequate insulation (R-40 to R-60) as is shown in Figure 2. In some cases, however, special framing methods at the eaves of the roof may be required to permit for full depth of insulation to extend over the outside wall. Also, proper attic ventilation must always be provided. An illustration of a typical truss detail used to allow the full depth of ceiling insulation to extend to the outer wall is shown in Figure 3.

Figure 2 Four examples of R-40 ceiling insulation.


Flat Ceiling
Cathedral Ceiling
Roof Finish
Airspace for Ventilation (vent at eaves and ridge)
2x6 Ceiling Joists
14" Fiberglass Loose Fill
2-5½" Fiberglass Batts (crosswise over joists)
10"-12" Cellulose Insulation
6-mil Polyethylene Vapor Barrier Under Joists
Gypsum Board
Fiberglass Batt Insulation
2x12 Roof Joists
1" Rigid Foam Insulation (R-7) (added when joists are 2x10 and optional for 2x12 joists)

Walls

Construction Options for Efficiency

Walls of standard design (see Figure 4) will not accommodate high levels of insulation (R-27 to R-40). There are two basic construction options: a double-stud wall or a single-stud wall with exterior insulation (Figures 5, 6, 8). The cost of both wall options is nearly the same; the builder's experience usually dictates which is preferable. Both options reduce heat loss through the studs since wood has a lower R-value than insulation materials (Figure 9). The single-stud wall with foam sheeting has practical limits to R-30 whereas the double-stud wall can be constructed to values exceeding R-40.

Usually, the south wall is constructed with 2" x 6"s, 24" on center, regardless of the rest of the structure. This is because the south wall has the most glass and doesn't experience temperatures as low as the other walls.

Figure 3 Use a raised truss that allows the full depth of insulation over the wall plate.

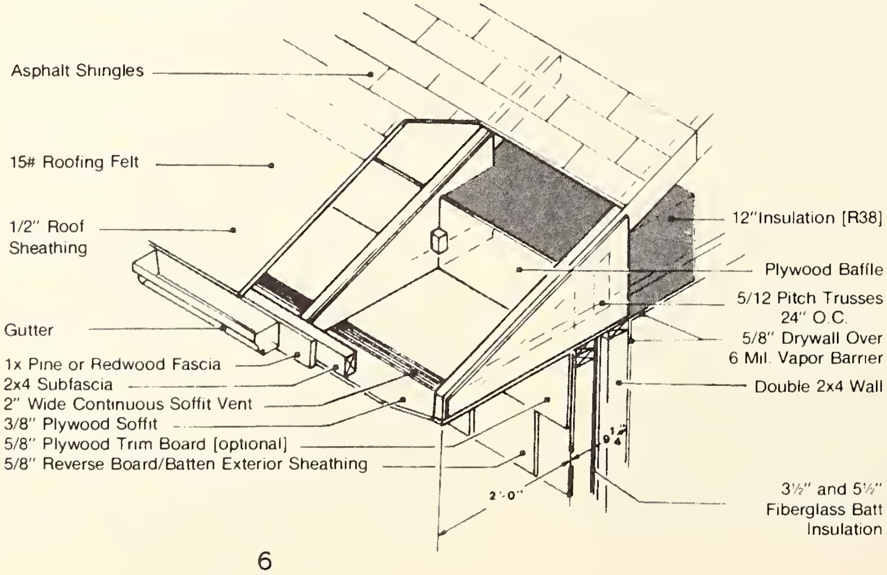
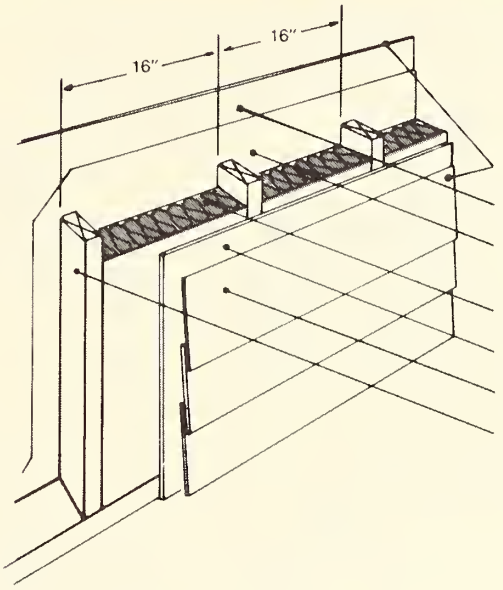
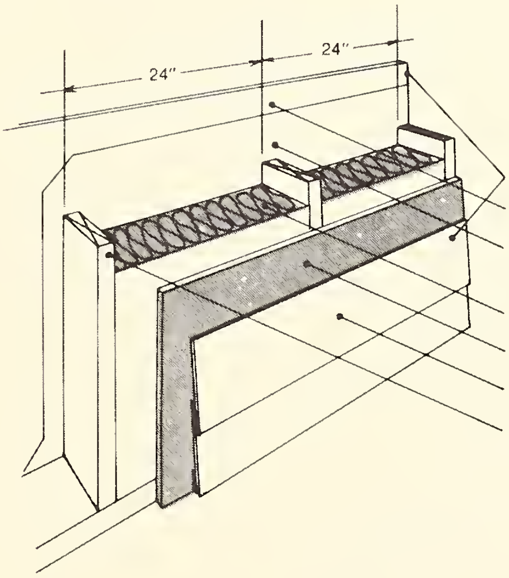

Asphalt Shingles
15# Roofing Felt
1/2" Roof Sheathing
Gutter
1x Pine or Redwood Fascia
2x4 Subfascia
2" Wide Continuous Soffit Vent
3/8" Plywood Soffit
5/8" Plywood Trim Board [optional]
5/8" Reverse Board/Batten Exterior Sheathing
12"Insulation [R38]
Plywood Baffle
5/12 Pitch Trusses 24" O.C.
5/8" Drywall Over 6 Mil. Vapor Barrier
Double 2x4 Wall
9¼"
2'-0"
3½" and 5½" Fiberglass Batt Insulation

Figure 4 Standard 2x4 wall construction.



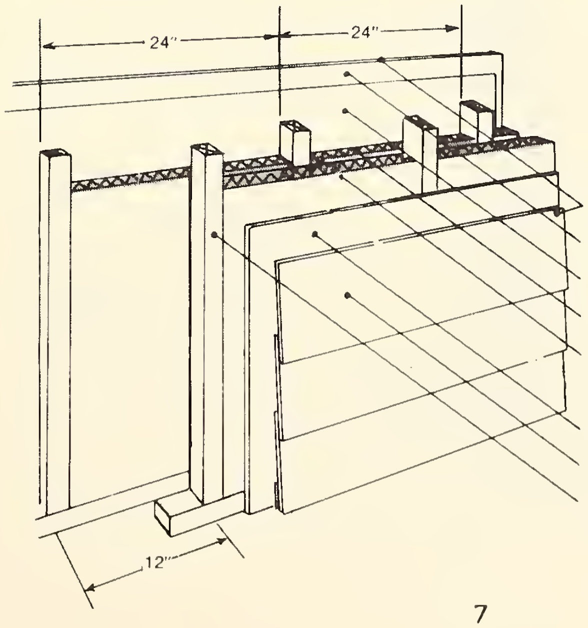
	R-Value
Air Films	0.9
½" Gypsum Board	0.5
Vapor Barrier	0
3½" Fiberglass Batt	11
25/32" Sheathing	2
¾" Wood Siding	1
2×4 Stud	
Total Resistance of Wall	15.4

Figure 5 2x6 wall construction.



	R-Value
Air Films	0.9
⅝" Gypsum Board	0.6
Vapor Barrier	0
5½" Fiberglass Batt	19
1" Rigid Foam Sheathing	8
¾" Wood Siding	1
2×6 Stud	
Total Resistance of Wall	29.5

Figure 6 Double 2x4 wall construction.



	R-Value
Air Films	0.9
⅝" Gypsum Board	0.6
Vapor Barrier	0
3⅝" Fiberglass Batt	13
5½" Fiberglass Batt	19
25/32" Sheathing	2
¾" Wood Siding	1
2×4 Stud	
Total Resistance of Wall	36.5

Figure 7 Attic insulation must be continuous.

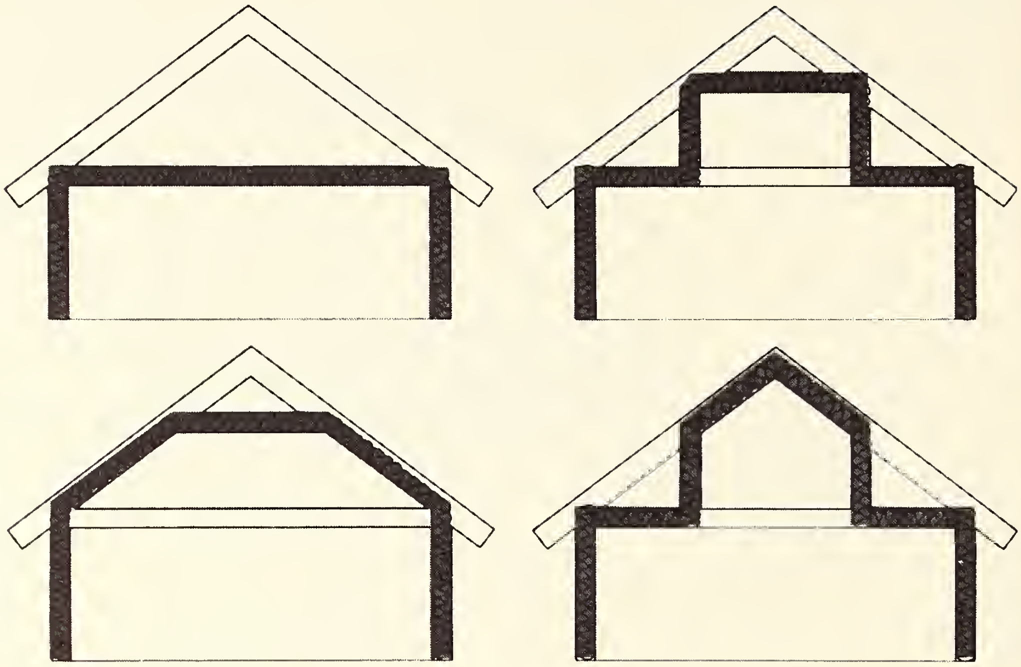
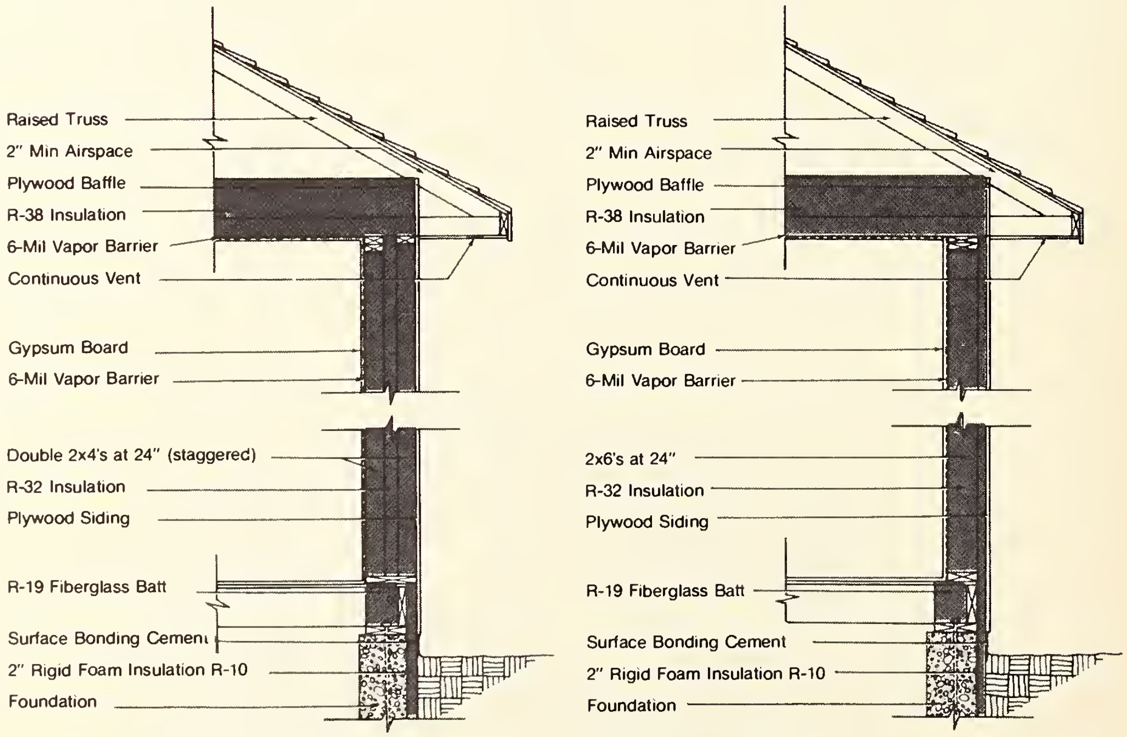


Figure 8 Two types of superinsulated walls for new construction.



DOUBLE 2x4 WALL FRAMING

2x6 WALL FRAMING

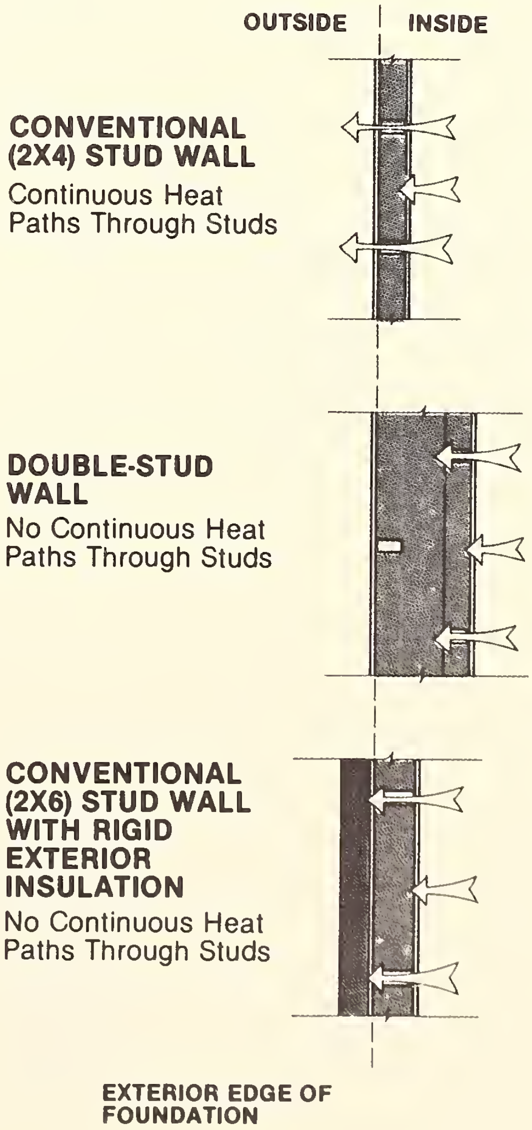
Construct for Greatest Energy Savings

Double-Stud Wall Construction

Standard 2″ x 4″ studs are used to build both an outer wall and an inner stud wall. Although this is not yet a common building practice, it is not a difficult wall to build. It offers the greatest potential for energy-saving construction. The sequence for building follows:

- Build the outer stud wall, tilt up and install in the conventional manner. This is the structural wall for the house and the studs may be either 24″ or 16″ on center.
- Install spacer blocks on the inside face of the top and bottom plates of the outer wall. These spacers determine the size of the gap between the two 2″ x 4″ walls and can range in thickness from 1½″ to 3½″ (R-30 wall to R-40 wall).
- Build the inner wall with 2″ x 4″ studs 24″ on center. This wall is not structural; it can be built with no substantial headers and a single top plate. Tilt the inner wall up against the spacers and square it using the outer wall as a guide. The studs on the inner and outer walls are offset by 12″ so that there is always a minimum of 6″ of insulation wherever a stud occurs.
- Connect the two walls at the top plates with bridging from scrap 2″ x 4″ or plywood.
- Windows and door openings are boxed in with ½″ plywood plates bridging the walls. Be sure to allow for the extra one inch in each dimension in measuring the rough openings.

Figure 9 Studs are a source of heat loss.


OUTSIDE
INSIDE
CONVENTIONAL (2X4) STUD WALL
Continuous Heat Paths Through Studs
DOUBLE-STUD WALL
No Continuous Heat Paths Through Studs
CONVENTIONAL (2X6) STUD WALL WITH RIGID EXTERIOR INSULATION
No Continuous Heat Paths Through Studs
EXTERIOR EDGE OF FOUNDATION

Double stud construction does not restrict the choice of exterior siding as foam sheathed 2″ x 6″ walls can. Other advantages are:

Advantages of Double Stud Construction

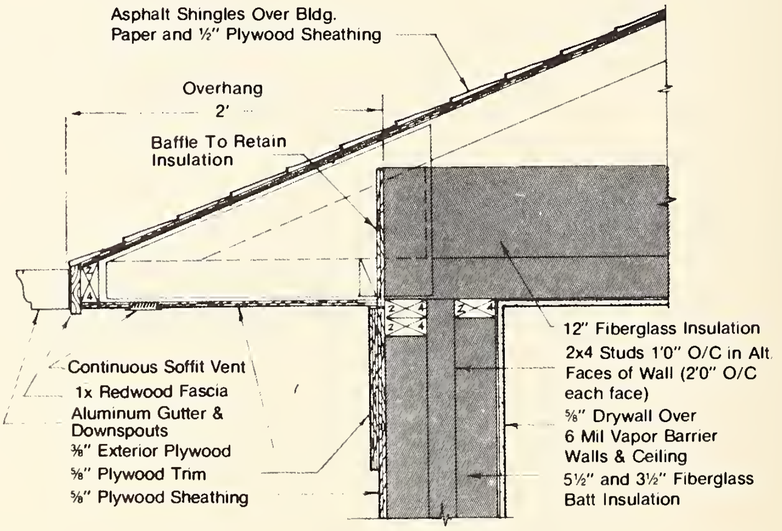
- electrical wiring can be run in the gap between the walls without drilling.
- the slot between the top plates permits venting of water vapor to the attic space.
- thick, insulated walls will reduce sound transmission.
- sliding panels to cover windows at night can be hidden within the wall.
- the energy-efficient construction can be easily noted by the homebuyer through the visible thickness of the walls.

Attractive Wide Sills

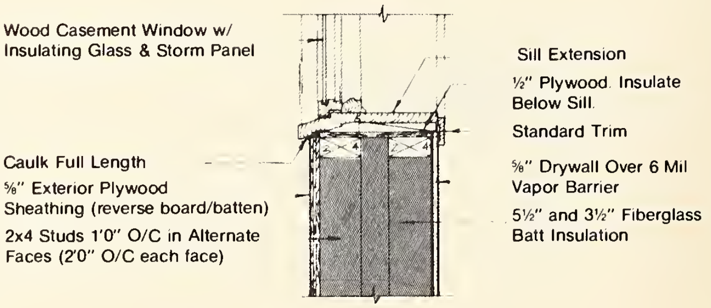
The wide sills around the windows and doors can be trimmed in wood or wrapped with sheetrock around all but the bottom sill which must be wood. The details of this method can be seen in the typical plan sections shown in Figure 10.

Figure 10 Typical double 2x4 wall framing details.

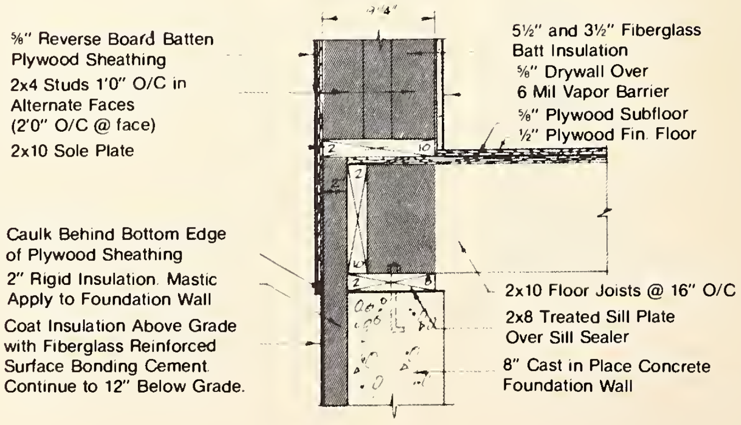
SOFFIT DETAIL


Asphalt Shingles Over Bldg. Paper and ½″ Plywood Sheathing
Overhang
2′
Baffle To Retain Insulation
2x4
2x4
2x4
12″ Fiberglass Insulation
2x4 Studs 1′0″ O/C in Alt. Faces of Wall (2′0″ O/C each face)
⅝″ Drywall Over 6 Mil Vapor Barrier Walls & Ceiling
5½″ and 3½″ Fiberglass Batt Insulation
Continuous Soffit Vent
1x Redwood Fascia
Aluminum Gutter & Downspouts
⅜″ Exterior Plywood
⅝″ Plywood Trim
⅝″ Plywood Sheathing

WINDOW SILL DETAIL


Wood Casement Window w/ Insulating Glass & Storm Panel
Sill Extension
½″ Plywood. Insulate Below Sill.
Standard Trim
2x4
2x4
Caulk Full Length
⅝″ Exterior Plywood Sheathing (reverse board/batten)
⅝″ Drywall Over 6 Mil Vapor Barrier
2x4 Studs 1′0″ O/C in Alternate Faces (2′0″ O/C each face)
5½″ and 3½″ Fiberglass Batt Insulation

SILL DETAIL


⅝″ Reverse Board Batten Plywood Sheathing
5½″ and 3½″ Fiberglass Batt Insulation
2x4 Studs 1′0″ O/C in Alternate Faces (2′0″ O/C @ face)
⅝″ Drywall Over 6 Mil Vapor Barrier
⅝″ Plywood Subfloor
½″ Plywood Fin. Floor
2x10 Sole Plate
2 10
2
2 8
Caulk Behind Bottom Edge of Plywood Sheathing
2″ Rigid Insulation. Mastic Apply to Foundation Wall
2x10 Floor Joists @ 16″ O/C
2x8 Treated Sill Plate Over Sill Sealer
Coat Insulation Above Grade with Fiberglass Reinforced Surface Bonding Cement. Continue to 12″ Below Grade.
8″ Cast in Place Concrete Foundation Wall

Single-Stud Wall Construction with Exterior Siding

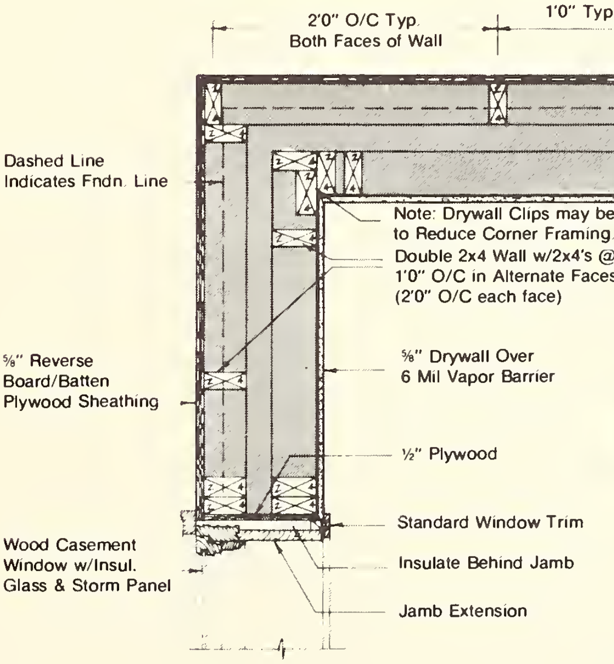
Rigid Insulation

The use of 2″ x 6″ studs on 24″ centers in framing is an alternative wall construction practice for an energy efficient house. However, to achieve the recommended R-value of an IDEAL home, rigid exterior insulation must be used; this may be high-density fiberglass panels or rigid foam panels. To achieve the required minimum R-value of 27, an additional R-8 must be added to the R-19 fiberglass batt. This can be accomplished with either 1″ of urethene foam or 2″ of fiberglass or polystyrene foam.

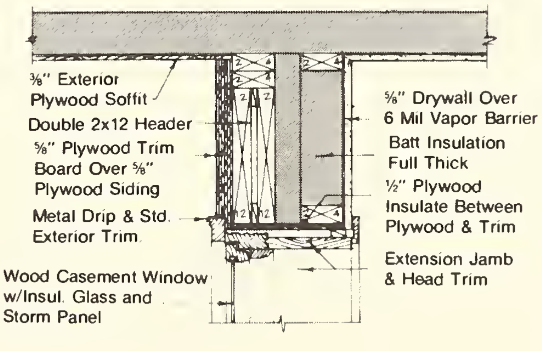
Hollow Insulated Headers

The extra thickness of rigid insulation is usually placed outside the studs or building foundation, thus limiting the siding options. To avoid excessive heat loss above doors and windows, hollow insulated headers should be constructed.

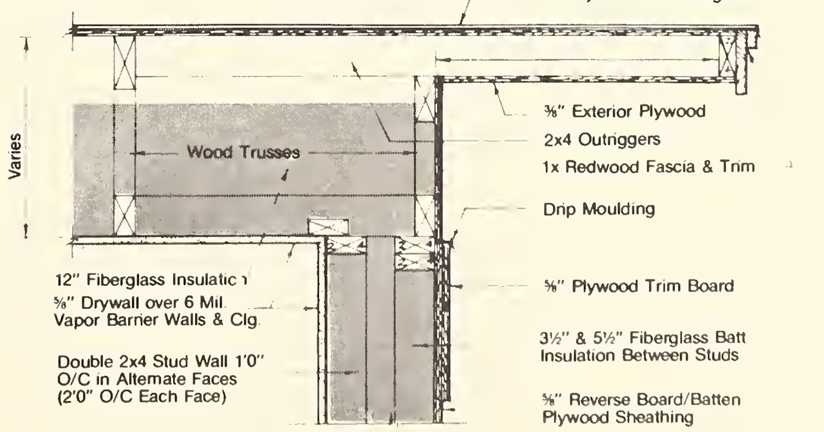
WINDOW JAMB

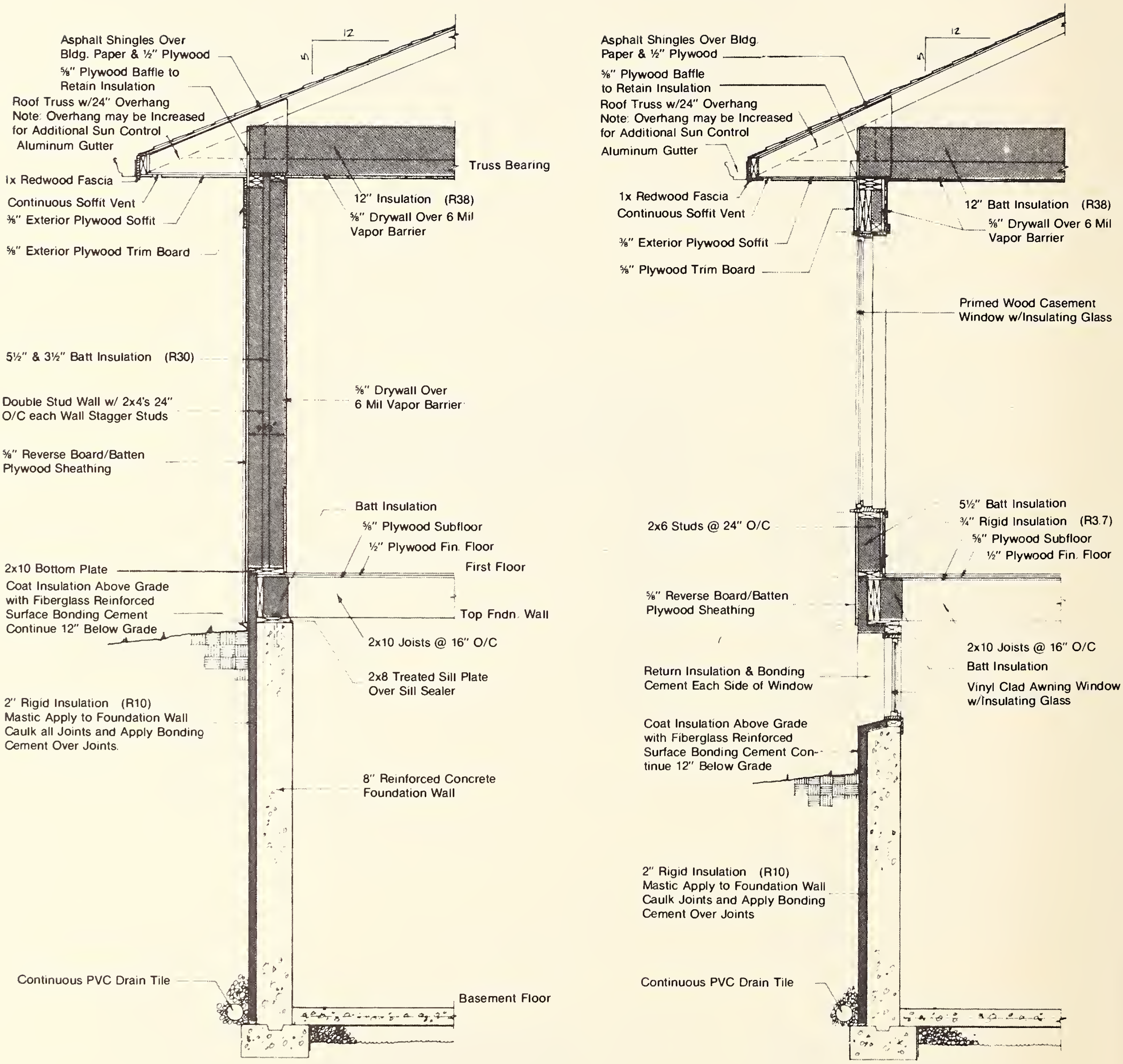

2'0" O/C Typ.
Both Faces of Wall
1'0" Typ.
Dashed Line Indicates Fndn. Line
Note: Drywall Clips may be used to Reduce Corner Framing.
Double 2x4 Wall w/2x4's @ 1'0" O/C in Alternate Faces (2'0" O/C each face)
⅝" Reverse Board/Batten Plywood Sheathing
⅝" Drywall Over 6 Mil Vapor Barrier
½" Plywood
Standard Window Trim
Wood Casement Window w/Insul. Glass & Storm Panel
Insulate Behind Jamb
Jamb Extension

WINDOW HEAD DETAIL


⅜" Exterior Plywood Soffit
Double 2x12 Header
⅝" Plywood Trim Board Over ⅝" Plywood Siding
Metal Drip & Std. Exterior Trim
Wood Casement Window w/Insul. Glass and Storm Panel
⅝" Drywall Over 6 Mil Vapor Barrier
Batt Insulation Full Thick
½" Plywood
Insulate Between Plywood & Trim
Extension Jamb & Head Trim

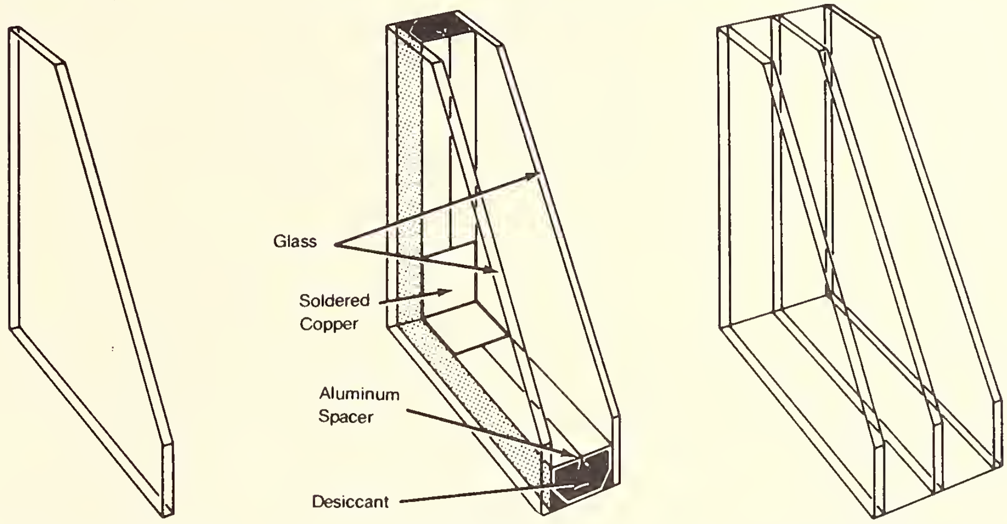
GABLE END SECTION


Asphalt Shingles Over Bldg. Paper
½" Plywood Sheathing
Varies
Wood Trusses
⅜" Exterior Plywood
2x4 Outriggers
1x Redwood Fascia & Trim
Drip Moulding
12" Fiberglass Insulation
⅝" Drywall over 6 Mil. Vapor Barrier Walls & Clg.
Double 2x4 Stud Wall 1'0" O/C in Alternate Faces (2'0" O/C Each Face)
⅝" Plywood Trim Board
3½" & 5½" Fiberglass Batt Insulation Between Studs
⅝" Reverse Board/Batten Plywood Sheathing


12
5
Asphalt Shingles Over Bldg. Paper & ½" Plywood
⅝" Plywood Baffle to Retain Insulation
Roof Truss w/24" Overhang
Note: Overhang may be Increased for Additional Sun Control
Aluminum Gutter
1x Redwood Fascia
Continuous Soffit Vent
⅜" Exterior Plywood Soffit
⅝" Exterior Plywood Trim Board
Truss Bearing
12" Insulation (R38)
⅝" Drywall Over 6 Mil Vapor Barrier
5½" & 3½" Batt Insulation (R30)
Double Stud Wall w/ 2x4's 24" O/C each Wall Stagger Studs
⅝" Drywall Over 6 Mil Vapor Barrier
⅝" Reverse Board/Batten Plywood Sheathing
Batt Insulation
⅝" Plywood Subfloor
½" Plywood Fin. Floor
First Floor
2x10 Bottom Plate
Coat Insulation Above Grade with Fiberglass Reinforced Surface Bonding Cement Continue 12" Below Grade
Top Fndn. Wall
2x10 Joists @ 16" O/C
2x8 Treated Sill Plate Over Sill Sealer
2" Rigid Insulation (R10) Mastic Apply to Foundation Wall Caulk all Joints and Apply Bonding Cement Over Joints.
8" Reinforced Concrete Foundation Wall
Continuous PVC Drain Tile
Basement Floor
12
5
Asphalt Shingles Over Bldg. Paper & ½" Plywood
⅝" Plywood Baffle to Retain Insulation
Roof Truss w/24" Overhang
Note: Overhang may be Increased for Additional Sun Control
Aluminum Gutter
1x Redwood Fascia
Continuous Soffit Vent
12" Batt Insulation (R38)
⅝" Drywall Over 6 Mil Vapor Barrier
⅜" Exterior Plywood Soffit
⅝" Plywood Trim Board
Primed Wood Casement Window w/Insulating Glass
5½" Batt Insulation
2x6 Studs @ 24" O/C
¾" Rigid Insulation (R3.7)
⅝" Plywood Subfloor
½" Plywood Fin. Floor
⅝" Reverse Board/Batten Plywood Sheathing
2x10 Joists @ 16" O/C
Batt Insulation
Return Insulation & Bonding Cement Each Side of Window
Vinyl Clad Awning Window w/Insulating Glass
Coat Insulation Above Grade with Fiberglass Reinforced Surface Bonding Cement Continue 12" Below Grade
2" Rigid Insulation (R10) Mastic Apply to Foundation Wall Caulk Joints and Apply Bonding Cement Over Joints
Continuous PVC Drain Tile

TYPICAL WALL SECTIONS

Figure 11 Windows are available with one, two, or three panes.



SINGLE GLAZING DOUBLE GLAZING TRIPLE GLAZING

Windows

Triple Glazing Recommended

Because windows lose heat almost like holes in the wall, special attention should be paid to them in a superinsulated home. Even double-glazed glass (less than R-2) provides an enormous heat loss when compared with adjacent walls. Triple glazing of windows (less than R-3) is an improvement and should be considered if the budget allows.

There are many new window innovations with special three and four-pane glazings that use plastic films for the center panes to significantly reduce heat loss.

Limit Total Glass Area to 15% of Floor Area

The simplest solution to cutting heat loss through glass is to limit the total glass area to 15 percent or less of the floor area and place two-thirds of the windows on the south. In general, south-facing glass will gain more heat than it loses over a full heating season. Skylights should be carefully placed, but avoided if possible. They don't gain as much winter sun as vertical south-facing glass and they admit a lot of summer sun.

Fixed Glass Preferred

To minimize air leaks every window in a house need not operate and every operable window should fit tightly. Fixed glass is less expensive, provides a better seal and should be used whenever practical. As a general rule, sliding windows tend to be poor performers because they must be loose enough to slide which makes good weather sealing difficult. Window manufacturers' literature provides air infiltration information helpful in construction and installation decisions.

Night Insulation Optional

To reduce heat loss even further, night-time window insulation can be used. Generally, the cost of the night insulation is not offset by the additional energy savings in a reasonable amount of time. The least expensive movable window insulation which the homeowner can make himself is a "pop-in" foam panel framed in wood and covered with fabric. More information on movable window insulation is referenced at the end of this booklet.

The builder using double-stud walls may wish to consider the use of sliding insulation panels which are hidden in the wall during the day and cover windows at night. This type of construction can be costly and difficult to justify from the resulting fuel savings. If the night insulation can substitute for drapes or the need for further window treatment, then the economics are more favorable. Possibly the best approach is to offer night insulation at an extra cost to the homebuyer.

Doors

Steel Foam Core Doors

The doors used in a superinsulated house also must provide good resistance to heat loss and have a good air seal. Hollow core doors are poor on both points. Steel doors with polyurethane foam cores and magnetic weatherstripping have proven the most satisfactory from an energy standpoint. The IDEAL house should have at least one double door "airlock" entry, (not necessarily on the front).

Foundation

R-10 to R-20 for Above Ground Foundation

With the walls and roof of the house superinsulated, the foundation becomes more important as a source of heat loss. The most critical area includes the top four feet of the foundation wall, especially the area exposed above the ground. Insulate this area to at least R-10 and preferably to R-20 with rigid foam or a stud wall and fiberglass batts.

Putting all of the insulation on the outside of a masonry foundation gives the best energy savings but presents practical problems. It's difficult to adhere thick foam to the foundation and to handle the junction with the siding. The IDEAL homes in this book use 2" of rigid insulation on the outside of the foundation with the recommendation that the inner wall be furred and insulated, later on if desired. The outside insulation keeps the basement walls warm and prevents condensation in almost all cases.

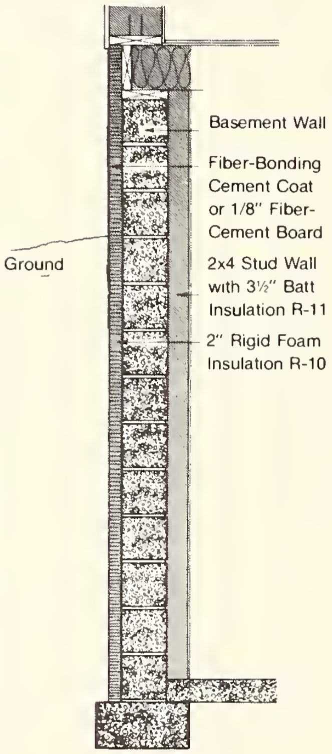

Basement Wall
Fiber-Bonding Cement Coat or 1/8" Fiber-Cement Board
Ground
2x4 Stud Wall with 3½" Batt Insulation R-11
2" Rigid Foam Insulation R-10

Figure 12 A practical and effective method of insulating a basement wall.

AIR TIGHTNESS

Sources of Air Leakage

While most people recognize the value of properly insulating, the importance of air tightness is not as well understood. A 1,500 sq. ft. house contains more than 1,000 pounds of air. The air leakage in a conventionally-built home would be equivalent to it having a single hole about two feet square in one wall. In a conventionally-built home the entire volume of inside air is replaced with outside air approximately every 90 minutes. Heating this outside air is responsible for about one-third of the total heat load of the house.

Recent research studies found that in average homes the sources of air leakage (other than those associated with the furnace and chimney) were approximately as follows:

• exterior walls and basement (electrical and plumbing penetrations, leakage under sill plate)	60%
• windows and doors	20%
• ceilings	20%

Open chimneys and fireplaces can also be a major path for air leakage. Typical leakage spots in standard houses are shown in Figure 21.

Vapor Barrier

Importance of Vapor Barrier

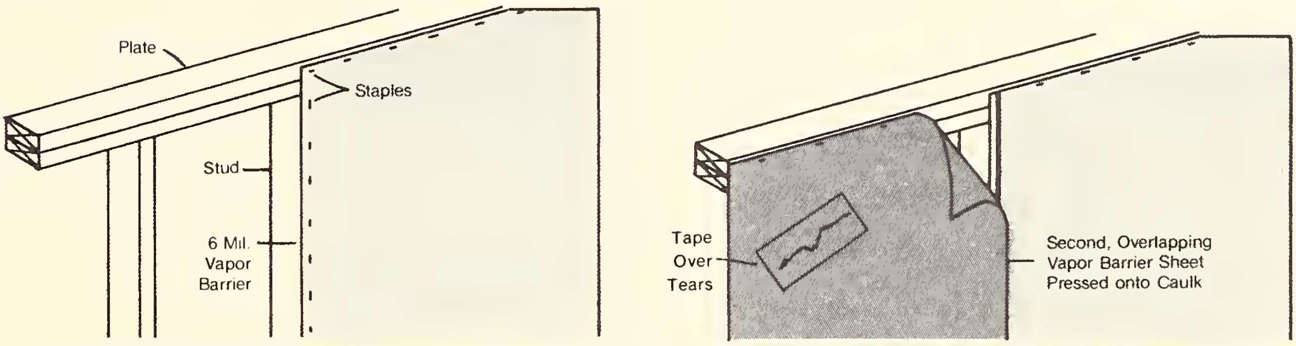
The most important factor in tightening a home is the installation of a complete vapor barrier. Essentially, the entire living space is wrapped in a "plastic bag" to stop air leaks and keep valuable heat inside. The vapor barrier also controls condensation by keeping water vapor out of the walls. Six-mil (.006") thick polyethylene is commonly used; it is placed on the interior (warm) side of all exterior surfaces. Thinner polyethylene will suffice, but is more prone to tear and damage. Foil-backed sheet rock can also serve as a vapor barrier.

Without a vapor barrier, warm moist air seeps into the cooler parts of the insulation. As this moist air cools, the water condenses which can cause rotting and ruins the value of the insulation. Many condensation problems occur when a lack of insulation creates cold spots on the walls and ceilings where the water vapor condenses.

Seal Holes in Barrier

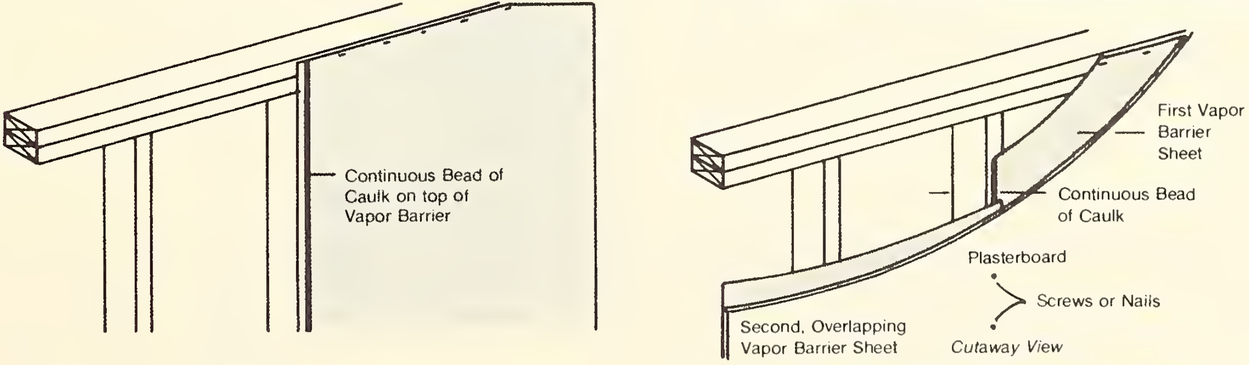
Ideally, a vapor barrier eliminates every spot where cold air leaks in and warm air leaks out. Seams should be overlapped and sealed with non-hardening caulk or plastic tape. Any holes in the vapor barrier required for electrical wiring, pipes and fixtures must be carefully sealed. The use of recessed lighting fixtures which penetrate the barrier on the ceiling should be eliminated.

Figure 13 Technique for joining vapor barrier sheets on wall studs (insulation not shown)



a. Staple 6 mil. vapor barrier to studs and plates

c. Overlap second vapor barrier sheet (always join the vapor barrier over a solid backing such as a stud)


Continuous Bead of Caulk on top of Vapor Barrier
First Vapor Barrier Sheet
Continuous Bead of Caulk
Plasterboard
Screws or Nails
Second, Overlapping Vapor Barrier Sheet
Cutaway View

b. Place a bead of caulk over top of vapor barrier, ensuring that the caulk is continuous and in line with the stud

d. Cover vapor barrier with rigid material (plasterboard, wallboard, etc.)

Installing a Vapor Barrier Requires Several Considerations

- Install the entire vapor barrier before the interior walls are in place. Use narrow (1 ft. wide) strips of polyethylene behind the studs and above the plates of interior walls to join with the main barrier.
- Staple the polyethylene (6 mil.) barrier to studs and plates.
- Overlap and double-fold all joints between the sheets and then caulk or tape air tight (polyethylene tape works best).
- Tape all tears or holes made during construction.
- Avoid outlets in outer walls and ceiling fixtures wherever possible. Carefully caulk and tape to seal barrier around necessary electrical boxes. Use foam gaskets behind these cover plates.

Figure 14
Vapor barrier at interior and exterior wall joint.

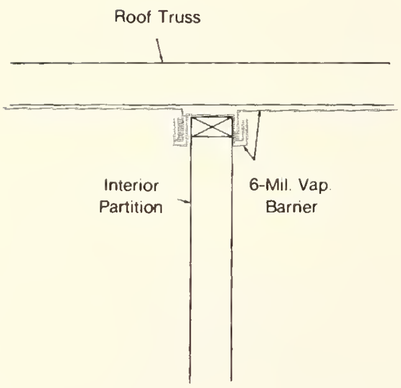


Figure 15
Vapor barrier at wall and floor.

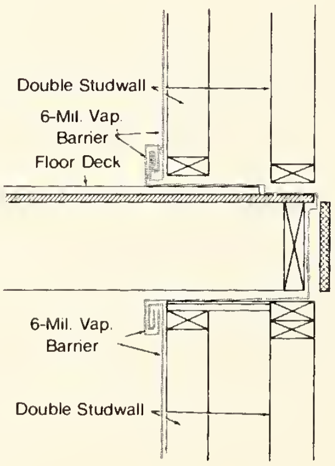


Figure 16
Vapor barrier at wall and concrete floor.

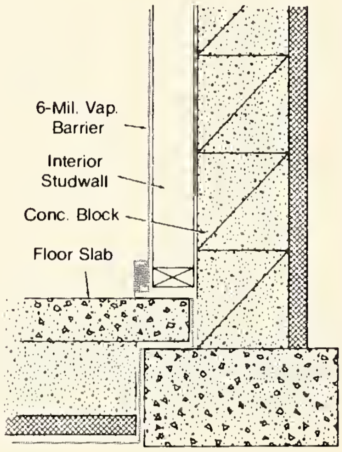


Figure 17
Vapor barrier at wall and truss.

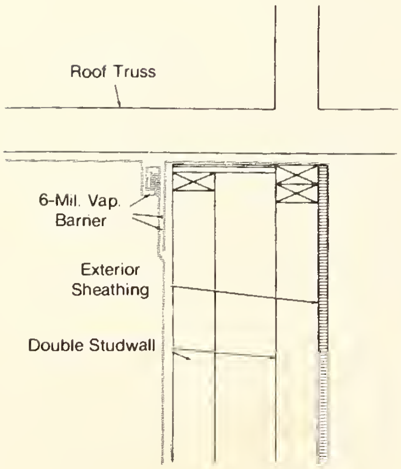


Figure 18
Vapor barrier and sealant at windows and doors.

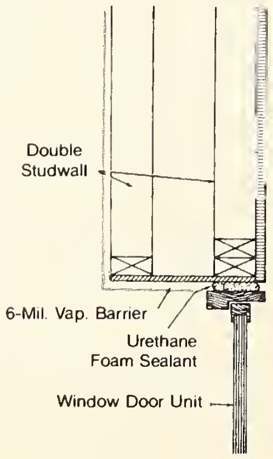


Figure 19
Vapor barrier installation around plumbing vent stack.

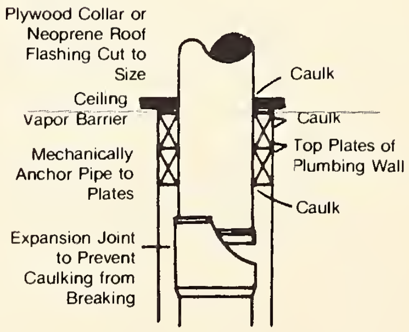
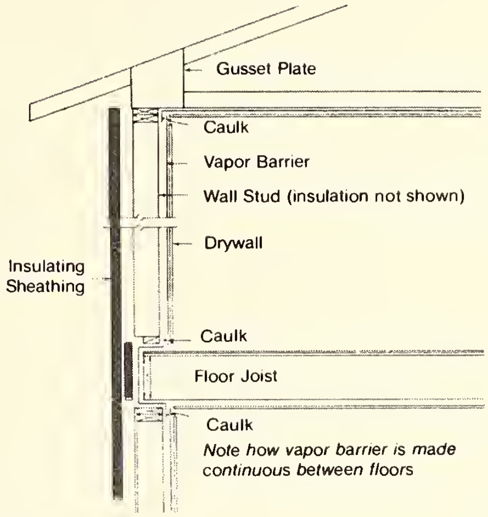

Plywood Collar or Neoprene Roof Flashing Cut to Size
Caulk
Ceiling Vapor Barrier
Caulk
Mechanically Anchor Pipe to Plates
Top Plates of Plumbing Wall
Caulk
Expansion Joint to Prevent Caulking from Breaking

Figure 20 Wall section—vapor barrier detail for 2x6 walls.

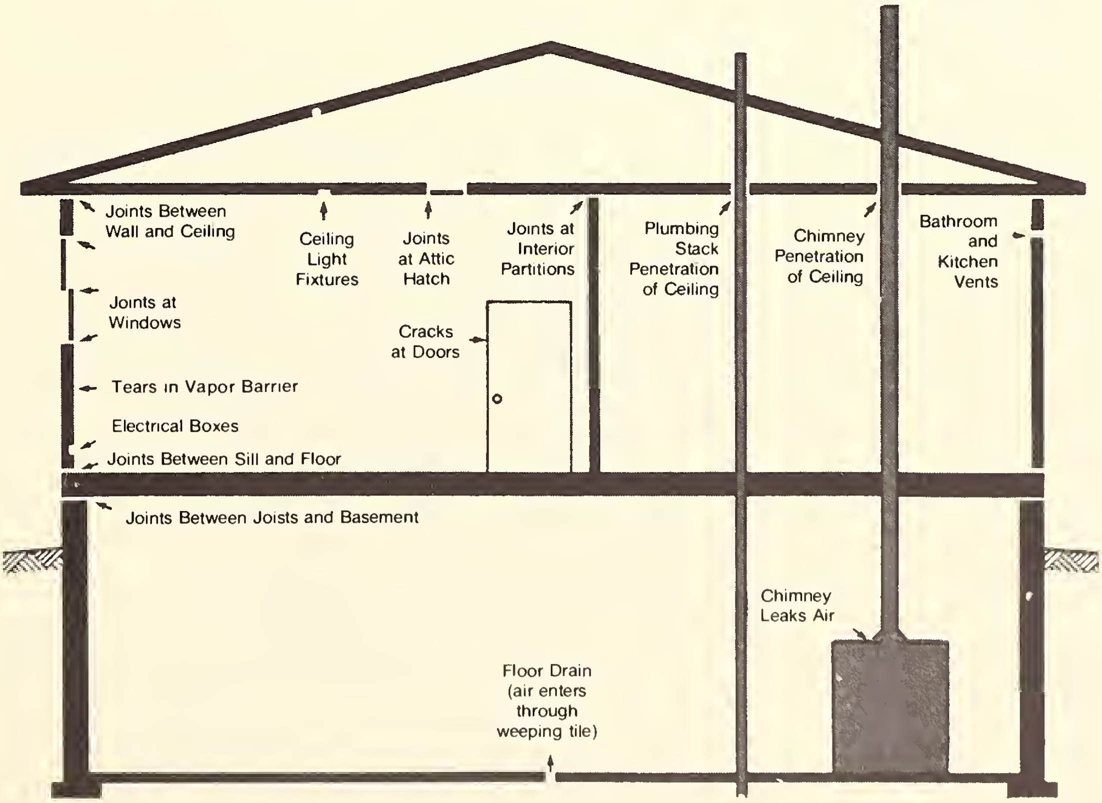

Gusset Plate
Caulk
Vapor Barrier
Wall Stud (insulation not shown)
Drywall
Insulating Sheathing
Caulk
Floor Joist
Caulk
Note how vapor barrier is made continuous between floors

Seal Gaps and Wall Penetrations

Foam sealant should be used around gaps between window frames and rough framing for air tightness (see Figure 18). Seal all wall penetrations such as utility entrances, plumbing stacks and dryer vents with caulking.

In the IDEAL house, air leakage cannot be tolerated. Proper ventilation, however, must be provided and this is done by a forced ventilation system described in the section which follows. It assures that inside air stays fresh and removes excess moisture.

Figure 21 Air leakage spots in conventional housing.


Joints Between Wall and Ceiling
Ceiling Light Fixtures
Joints at Attic Hatch
Joints at Interior Partitions
Plumbing Stack Penetration of Ceiling
Chimney Penetration of Ceiling
Bathroom and Kitchen Vents
Joints at Windows
Cracks at Doors
Tears in Vapor Barrier
Electrical Boxes
Joints Between Sill and Floor
Joints Between Joists and Basement
Chimney Leaks Air
Floor Drain (air enters through weeping tile)

AIR-TO-AIR HEAT EXCHANGER

An air-tight house reduces energy loss from the flow of air in and out of the house, but it presents the problem of stale air. The air in a conventional house is replaced by outside air every 90 minutes just by normal air leakage. Natural ventilation in a tight house changes the air about only once in five hours.

Stale Air Can be a Problem

Fresh air is needed to dilute pollution from smoking, unvented gas appliances, vapors from certain building materials and cooking odors. Humidity is also controlled by ventilation. Devices such as furnaces, water heaters and fireplaces need fresh air for combustion. It is impractical to open a window for fresh air in the winter, so an air-to-air heat exchanger is recommended to ventilate the home.

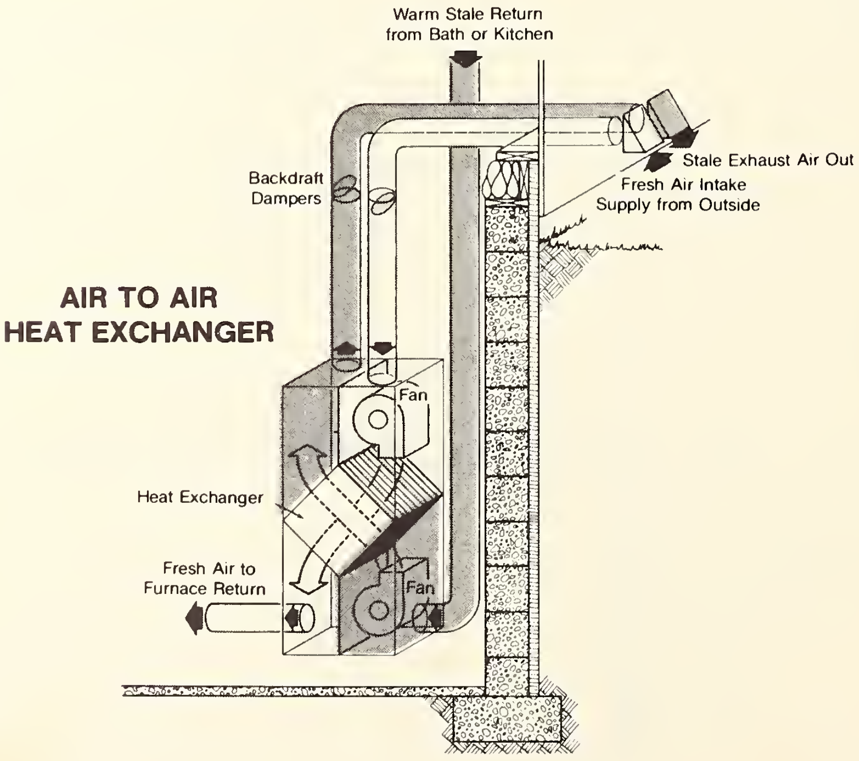
Fans Furnish Ventilation

The heat exchanger utilizes fans to pull stale air from the house and replace it with fresh air from the outside, as illustrated in Figure 22. The warmth of the stale air preheats the cold fresh air. About 70 percent of the heat is exchanged from the warm exhaust air to the cold fresh air in a series of small passages in a heat exchange core. The two airstreams are physically separated, but heat is transferred through the walls between the passages in the core.

Two Types of Exchangers

Ready-built units are available, as are plans for building heat exchangers (see reference list at the end of the booklet). Air-to-air heat exchangers function as small, self-contained units that replace normal bath exhaust fans or as central units the size of a water heater connected to a forced-air heating system. Which to use depends upon the size of the house and whether or not a central air system is being installed. Homes less than 1,500 sq. ft. can use one or two of the self-contained units; larger homes are best fitted with a central model.

Figure 22 Airflow in an air-to-air heat exchanger.


Warm Stale Return from Bath or Kitchen
Stale Exhaust Air Out
Fresh Air Intake Supply from Outside
Backdraft Dampers
AIR TO AIR HEAT EXCHANGER
Fan
Heat Exchanger
Fresh Air to Furnace Return
Fan

PASSIVE SOLAR

Reduce Heat Load First

The most cost-effective construction application of passive solar techniques is to use a moderate quantity of direct-gain, south-facing windows. A moderate quantity is defined as eight to 12 percent of the floor space devoted to utilizing the sun for heat.

The IDEAL homes are value designed for the most cost-effective measures. This means that the majority of the investment for energy efficiency should be spent on reducing the heat load using the techniques already mentioned. It then takes only a small amount of solar glazing to provide a substantial amount of heat gain.

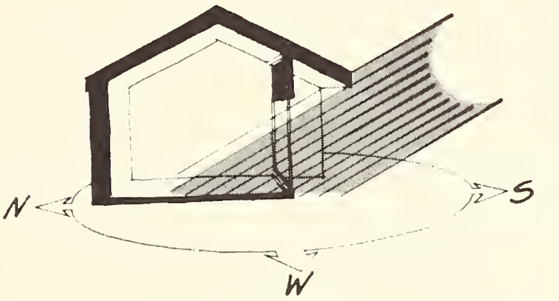
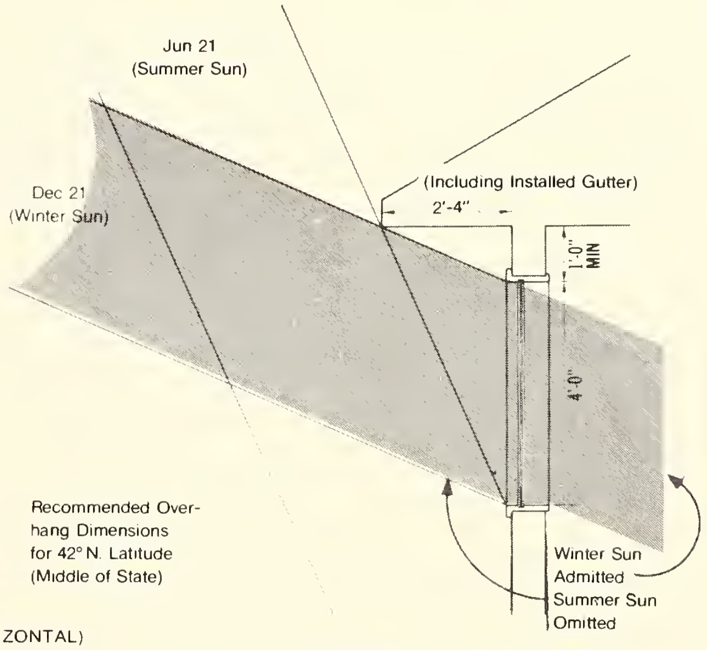


Figure 23 South-facing windows that gain in the winter are protected by eaves in the summer.

Figure 24 Use of an overhang to limit summer sunshine into house.



Recommended Overhang Dimensions for 42° N. Latitude (Middle of State)

SUN ANGLE FROM (HORIZONTAL)

JAN 21	FEB 21	MAR 21	APR 21	MAY 21	JUN 21	JULY 21	AUG 21	SEPT 21	OCT 21	NOV 21	DEC 21
28	37.2	48	60	68	71.5	68.6	60	48	37.5	28	24.5

Thermal Mass Storage

Passive solar techniques require "thermal mass", usually in the form of masonry, to store excess daytime solar energy and limit overheating with the recommended amount of south-facing glass. Relatively small slab/tile floors or interior brick walls can provide sufficient thermal mass to control interior temperature gains. Although increasing amounts of south-facing glass can reduce heating bills further, the added expense of thermal mass reduces the cost effectiveness.

Sunspaces

Designs with sunspaces can supply additional living space and are good sales features although they are expensive. In some designs, sunspaces are optional or can be added later. Sloped overhead glazing looks glamorous and generally is attractive to homebuyers, but adds little to solar performance. It tends to be:

- more expensive,
- harder to weather seal than vertical glass, and
- can present overheating problems in the summer.

Use sloped glazing and skylights with caution.

A SMALLER HEATING SYSTEM

Less Costly Heating System

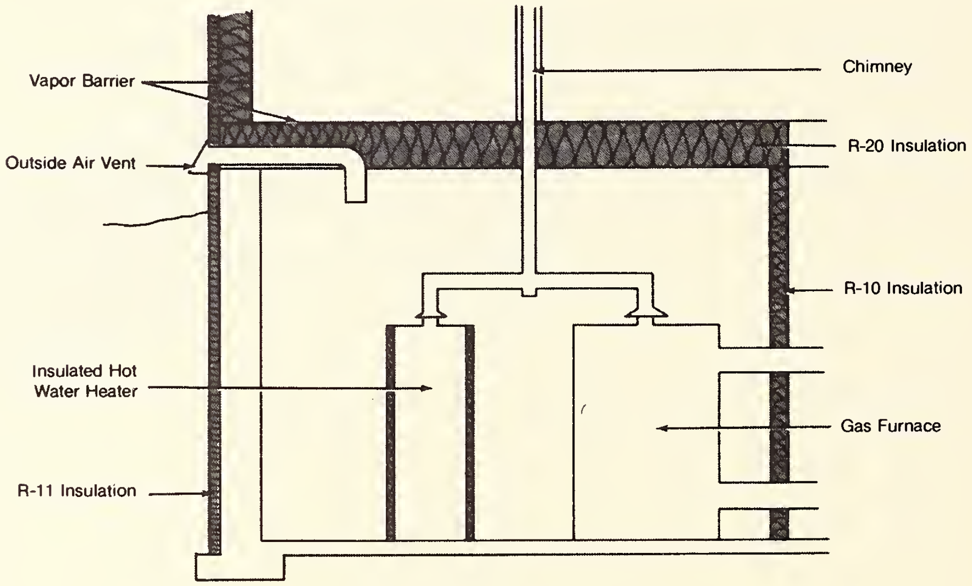
Even in a home with superinsulation, a heating system is still needed. The system, however, can be sized much smaller than one for a conventional house because the energy efficient structure demands much less heat. This down-sizing of the heating (and cooling) system helps offset the cost of extra insulation and tight construction.

The basic options in selecting a heating system are either a combustion furnace using gas or wood, or an all-electric system.

Air for Combustion

In any combustion system, the airtight nature of a superinsulated house must be considered carefully. Because there are so few air leaks, drawing air from living space for combustion purposes is not recommended. Furthermore, noxious fumes from a poorly drawing flue could build up in the living space to a dangerous level.

Figure 25 **Use of a furnace room to isolate fuel burning equipment from the rest of the house.**



Special Construction Techniques are Costly

If a combustion system is used, special precautions must be taken. Combustion draft air systems should be totally isolated from the living space, as illustrated in Figure 25. Unheated outside air should be ducted directly to the combustion device—furnace, fireplace, wood stove or water heater—to prevent the depletion of oxygen from the house. Care must be used to install the flue properly to prevent the danger of indoor pollution. In the case of gas devices, spark ignition systems should be installed to eliminate gas wasting pilot lights.

Improved Availability of Units

At the present time, the biggest difficulty facing builders who wish to use natural gas or propane heating systems is sizing; most manufacturers simply don't offer furnaces that are small enough. A furnace rated at 10,000 to 30,000 BTU/hour would be adequate for a superinsulated home of 1,100 to 1,800 sq. ft. But the smallest furnaces currently available are rated at 40,000 to 60,000 BTU/hour. An oversized furnace runs less efficiently than a correctly sized one. However, manufacturers are now responding to the growing market for small and efficient units.

Electrical Units Used

Many contractors are installing electric heat to avoid this difficulty. Electric baseboard units, electric radiant ceiling heat and even small electric furnaces (with air distribution ductwork) have been used successfully in energy efficient houses. The initial costs are less and although the heating bills are higher than with a combustion unit, they are still low compared to a conventional house. Electricity is currently about three times more expensive than natural gas and one-and-one-half times more expensive than propane. That gap, however, will narrow and the choice between combustion and electric heat will be a tradeoff between initial investment and local fuel costs.

EARTH SHELTERING

Earth Berming Helps

Earth sheltering—does it work? Yes, in that covering all or part of a house with earth can save energy. However, it does require special building techniques and doesn't always make economic sense. Requirements for structural reinforcing, waterproofing, drainage and insulation are all more critical and expensive compared to above ground construction. In many cases the resulting energy savings do not justify the added costs. This is particularly true of earth on the roof.

What does make sense is to construct the normal basement as earth-sheltered living space by paying special attention to insulating and waterproofing the walls. Another earth-sheltered approach that doesn't add much cost is berming. Berming earth against the walls up to four feet high reduces heat loss and air leakage. Any house design using earth-sheltering, including using the basement as living space, should pay special attention to the following points.

Points to Remember

- Waterproofing and drainage — use a continuous sheathing of synthetic rubber, vinyl or PVC from the bottom of the footing to the top plate. Polyethylene sheet or spray on coatings will not work over the long run. Use continuous drainage tubing around the perimeter of the footings.
- Insulate the outside of concrete walls with at least 2″ of rigid foam. Besides reducing heat loss, this will keep the wall warmer and reduce the chance of condensation.
- Make sure that the structural reinforcing is professionally designed. If the plans are not specific on this point, consult a structural engineer.

FOR MORE ENERGY INFORMATION

Energy Information Centers

The Energy Division of the Department of Natural Resources and Conservation, working with the Montana Cooperative Extension Service, has set up 60 Energy Information Centers around the state. The centers offer over 50 free publications on energy conservation and renewable energy sources. For the location of the nearest Energy Information Center, call your County Extension Office.

The following free publications are available at the Energy Information Centers or from the Energy Division, DNRC, Capitol Station, Helena, MT 59620:

***Twelve Ways to Turn Down High Energy Bills.** This brochure lists no-cost and low-cost steps you can take to reduce your energy bills.

***Do-It-Yourself Home Weatherization Guide.** Bonneville Power Administration produced this 48-page booklet describing how to insulate attics, floors, pipes, ducts and walls. It also gives step-by-step instructions for weatherstripping and caulking as well as tips on vapor barriers, ventilation and storm window selection.

***Mobile Home Energy Savings.** "Keep comfort up and costs down" is the theme of this 61-page book. It shows how to: keep pipes from freezing in the winter; wrap your hot water heater with a blanket of insulation; stop drafts; skirt, side and insulate; use vapor barriers to protect your insulation; and get the most out of your swamp cooler.

***Montana Energy Tax Benefits.** This nine-page guide covers the state and federal tax credits and exemptions for energy conservation and renewable energy.

***The Montana Renewable Energy Handbook.** The 114-page handbook gives a thorough introduction to renewable energy systems, including solar, wind, hydro, biomass and geothermal. The handbook includes examples of the technologies in use in Montana.

***Montana Sunpower: Volume I — Active Solar Homes.** Active solar heating, system design and construction are covered. Comments and suggestions from Montanans who installed active solar systems on their homes are also included.

***Montana Sunpower: Volume II — Passive Solar Homes.** Samples of cost-effective passive solar homes and greenhouses that have been built in Montana are described in this book. Building materials, construction techniques and system performance are covered.

***Building the Ideal Home.** The ideal home described in this booklet includes a high level of insulation, passive solar orientation, a continuous vapor barrier and an air-to-air heat exchanger to keep indoor air fresh.

***Montana's Energy Resources** is a series of eight-page brochures. Each brochure describes how an energy resource is being used in Montana, gives a brief introduction to the technology and includes a suggested reading list. The series includes booklets on **wind, small-scale hydro, geothermal** and **alcohol fuel.**

***The Montana Energy Resources Guide.** Designed for teachers and youth group leaders, the guide lists sources of speakers, films, video-tapes, slide shows and publications on energy conservation and renewable energy resources.

***Guide to the Renewable Report Library.** Abstracts of the final reports on the major DNRC-funded renewable energy projects are included in this guide. Copies of the full reports can be borrowed from the Montana State Library.

***Moisture and Home Energy Conservation.** This 34-page booklet tells how to detect, prevent and correct moisture problems in the home.

***Using the Earth to Heat and Cool Homes.** This 22-page booklet discusses the installation, economics, reliability and performance of heat pumps that use low-grade geothermal energy and earth-tempered air to heat and cool homes.

***Major Energy Conservation Retrofits: A Planning Guide for Montanans.** This 72-page guide shows builders, architects and skilled homeowners state-of-the-art strategies for insulating roofs and walls. Determining the most cost-effective ways to increase the thermal efficiency of building envelopes is also covered.

***How to Reduce Energy Costs in Your Building.** This 54-page booklet offers energy- and money-saving tips for businesses. The emphasis is on techniques that are simple and don't require capital investments.

OTHER SOURCES OF FREE INFORMATION

Your city or county library offers a wealth of information on all energy subjects. Your local utility can provide information on home energy conservation. Hardware stores and lumber suppliers can help explain the proper use of the many energy-saving products they sell.

The National Appropriate Technology Assistance Service answers questions about energy conservation and renewable energy resources over its toll-free lines. For assistance call 1-800-428-1718 in Montana from 8 a.m. to 5 p.m. weekdays or write NATAS, P.O. Bo 25254, Butte, MT 59702/2525. The service is for homeowners, renters, energy innovators, small businesses, farms, state and local governments, non-profit organizations and educational institutions. It's operated by the National Center for Appropriate Technology for the U.S. Department of Energy.

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

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